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ABSTRACT

Basic science is a process by which new knowledge is discovered; engineering is the process by which this new knowledge is made useful for practical situations or to solve particular problems. In education, new products are developed, research is completed, and the knowledge base is expanded, but there is no corollary to the engineer to make applications and solve problems with the information produced. The Central Susquehanna Intermediate Unit, as a regional education service agency, has attempted to establish the concept of educational engineering and, through multiplier training, has also attempted to establish "resident engineers" in each participating school district. (Author)

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EDUCATIONAL ENGINEERING--SCHOOL IMPROVEMENT THROUGH ECONOMICAL APPLICATIONS OF RESEARCH

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TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC) AND USERS OF THE ERIC SYSTEM."

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Research Utilization

Generally, the results of research in education have shown few definitive results toward changing traditional school activities. Questions are frequently raised concerning the effect of educational research on the daily operations of school classrooms. In fact, some would say that there is little direct connection between research and practice in schools (Howe, 1976; Kerlinger, 1977).

There is increasing concern throughout the nation for greater accountability of research and development in education. Local, state, and federal government officials are being prodded by the public and its elected representatives to account for the millions of tax dollars that have supported educational research and development projects. The growth of the ERIC system, a continuing interest in the development and coordination of an interlinking nationwide information dissemination system, and the NIE's focus on information dissemination for problem-solving, represent the current fascination of the educational community toward fulfilling government demands for accountability of federal and state funds for education.

Piele (1975) noted that "the federal government's investment in educational research during the past decade has produced a substantial accumulation of information about educational programs and their administration, as well as available resources to facilitate their operation" (pg. 1). He laments the failure of the schools to apply the knowlege gained from this research for the

improvement of education, and proposes that a linking agent can facilitate school change by producing interaction between the schools and the research information system.

The primary role of a linking agent is the application of information to school operational realities. The consequence of this role emphasis is a predisposition toward applied research, but Kerlinger (1977) has stated that basic research is more important than applied research in its potential effect on education. For this paper, however, the differences between basic and applied research will not be distinguished; instead, the term "research" will refer to a critical and exhaustive investigation to seek answers to basic questions or solutions to applied problems. In this sense, it is assumed that research information is available which educators might find relevant and useful to improve the scientific aspects of education.

Lutz (1970b) has written that instructional situations are needed in which a given proportion of learners can be successful each time these situations are implemented; in other words, instruction is needed that can replicate situations in which successful learning will occur (that is, "scientific instruction"). It is assumed that reliable and applicable information, even if it is somewhat limited, is available to make education more effective, and a start toward replicable scientific teaching can be affected.

Educational effectiveness and cost efficiency may be sacrificed, however, if research information is used in isolation and out of context of a larger theoretical framework. In addition to reviews and summaries of the literature, syntheses of axioms and assumptions should be provided to develop proto-theories and theories for further systematic work in educational research and a compilation

of effective instructional techniques for the practioner. With such a theory base, systematic research can then begin to test and revise its assumptions and identify effective and predictable instructional techniques for application in the schools (Lutz, 1970a, 1974).

The Role of Linking Agents

A review of the literature on educational information dissemination traces the emergence of educational linking agents (RISE, 1974). The role of the linker is to receive, process and fulfill requests for information needed to resolve specific educational problems. To date, various aspects of the linking role have been shared by a variety of professionals with varying degrees of success. Throughout the literature, the linking agent has been referred to as a change agent, educational extension agent, educational field agent, liaison researcher, intermediary, facilitator, process leader, service coordinator, catalyst, analyst, and information coordinator. Most of these terms can be subsumed within a model proposed by Havelock (1973). Havelock's four categories of linking agents are described as follows:

a) catalyst--"energizer," of the problem-solving process; helps overcome inertia; pressures and prods the system toward needed change;

b) solution giver--provides solutions (and alternatives); nondirective assistance; consultant;

c) process helper--demonstrates "how to"; attacks the various stages of the problem-solving process;

d) resource linker--helps find and makes use of many internal and external resources for the school system.

The linking agents described by Havelock, as well as the different terms listed previously, are included in the broad generic description afforded the term "linking agent" defined by Crandall (1977). Crandall's description of linking agents can accommodate a broad range of information coordinator roles. The linking agent is simply "an individual who helps others engaged in problem-solving by connecting them to appropriate resources" (pg. 216). Generally, the linking agent is viewed as a person or team to help bridge the gap between resource information and its operational implementation in schools.

In spite of these general role descriptions and the generic definitions of linking, an operational definition for the linking agent remains somewhat nebulous. Lavin (1972) noted that role definition is affected by the structure and operation of the parent organization and is controlled by such variables as the type of person desired, the training needed, available salaries, and the number of qualified people available. One of the more popular conceptions of this notion has been implemented by the Rhode Island Department of Education and described by Mojkowski (1974). The rationale supporting the Rhode Island Program Development Consultant (PDC) was an adaptation of a model from the National Center for Education Communication which advocated the use of full-time information consultants located in local districts. The primary purpose of the PDC was to link the client to the state information center and other problem-solving resources; thus, it became a Havelock resource linker. The key concept in the PDC extension agent system is "process generalist." The PDC role definition stressed the consultant's responsibility in helping clients determine and articulate problems, and assisting in the decision-making, implementation and evaluation processes. Training for the PDC included information retrieval; linkage to sources of funding, expert consultants, and training programs; interpersonal

communication; needs assessment and planning; dissemination and change strategies and research and evaluation techniques. This role is not compatible to the notion of the PDC as a subject specialist.

Brickley (1976) has felt strongly about the need to develop and expand the linking agent role concept to that of process generalist. The process generalist would be knowledgeable and skilled in the areas just described and would use appropriate resources when the need for a specialist arose. Regardless of an operational role definition, Herlig's (1973) research does support the use of linking agent activities for increased dissemination and utilization of educational R and D products in the schools.

Several projects have been implemented to evaluate and refine definitions for different linking agent models. These have been summarized in Table 1. Most of these projects were designed for the retrieval and dissemination of information and generally provide packets of research information related to a school client's request. The consultation provided by the linker is brief and little or no follow-up is provided.

Information from the constituents of the Central Susquehanna Intermediate Unit (the CSIU is a regional education service agency) has indicated a real concern for intervening and improving the school curriculum. Also, they have requested help in evaluating the effectiveness of district programs, finding information on innovative programs, and planning inservice programs for all professional staff. A concern of both teachers and administrators centered on how to obtain these needed services, given the limited and strained financial resources of each district. An effective delivery system for these requested services was proposed through an individualized and personalized linking approach to the unique needs and problems of each district.

TABLE 1
A Sampling of Linking Modal Projects.[4]

PROJECT	LOCATION	LINKERS	FOCUS	INTERVENTION	FOLLOW-UP
ERIC	National.	No direct linkers with local schools.	Information storage, retrieval, and dissemination.	Request from client, information provided.	None
Project Communicate	Kansas	Primarily librarians, later field agents.	Information storage, retrieval, and dissemination.	Request from client, information provided.	None
Network for Obtaining Resource Materials for Schools.	Iowa	Media center staff, field representatives.	Information storage retrieval, and dissemination.	Request from client, information provided.	None
Research Information Services for Education	Pennsylvania	Regional information coordinators.	Information storage, retrieval, and dissemination.	Request from client, information provided.	None
Research Utilization Project	Washington, D.C.	Extension agents, school librarians.	Information retrieval and dissemination for reading improvement.	Needs assessment, information and analysis provided.	Some
Pilot State Dissemination Project	Oregon	Field agents, district offices.	Information storage, retrieval, and dissemination.	Information retrieval, personal review.	Some
Pennsylvania School Improvement Project	Pennsylvania	Local and School Assistance Teams.	Information retrieval and dissemination for reading and mathematics improvement.	Needs assessment, information and analysis, consultation provided.	Long term involvement during planning, implementation, and evaluation.
Program Development Consultant	Rhode Island	Program consultants, field agents.	Information retrieval and dissemination for program improvement.	Information retrieval, direct assistance.	Long term involvement during program deve development and evaluation.
Educational Engineering	Pennsylvania	Engineers.	Information retrieval, design of recommendations for program improvement.	Negotiation and inter-personal collaboration.	Long term involvement during all phases.

*This is an incomplete sample taken primarily from information provided by RISE (1974). The original RISE information packet included a more comprehensive listing of projects; descriptions and analyses of all projects are being planned by the Educational Engineering Project.

Since local needs dominate the local decision-making process, attempts to help solve educational problems in schools must be done on the local level. In this case, the linking agent should help specify the local need, identify local R and D outcomes which have potential for meeting those needs, provide linkages between the school and appropriate R and D agencies, and monitor the installation and evaluation of newly designed activities for satisfying the original needs. In an attempt to improve the quality and durability of the linking agent's efforts, as well as to satisfy school needs for something more than just information retrieval and dissemination, another linking model has been defined and is described in this paper.

Engineering as a Linking Process

Basic research is a process by which new knowledge is discovered; the prime concerns of the scientist are the validity of theories, reproducibility of experiments, and adequacy of methods to observe natural phenomena. Engineering, on the other hand, is the process by which this new knowledge is made useful for practical situations or to solve particular problems; the prime concerns of the engineer are for economical feasibility, safeness, public acceptance, and manufacturability (Krick, 1965). In education, research is completed and the knowledge base is expanded, but there is no corollary to the engineer to make applications and solve problems with the information produced. According to Carlson, et.al. (1974), the slow rate of change in public schools lies, in part, with the absence of a change agent, or as proposed in this paper, with the absence of an engineer.

Thring (1972) has defined engineering as the application of scientific or practical knowledge for the satisfaction of the needs and wishes of humankind. Whinnery (1965) summarized the definition of engineering as prepared by the Engineering Council For Professional Development: "Engineering is the profession in which a knowledge of mathematical and natural science gained by study, experience, and practice is applied, with judgment, to develop ways to utilize, economically, the materials and forces of nature for the benefit of mankind" (pg. 57).

Engineers engage in research, design, and implementation of projects which are both economical and valuable to society. There are several engineering functions which include creative design, applied research, products development, cooperative management, production, and sales. Engineers use research, theory, and experience to design useful and needed products; they also evaluate them for efficiency, cost, and reliability. The industrial engineer, for example, works with people, money, materials, and management, and is responsible for designing production facilities, selecting equipment, and showing people the best way to do a job.

The engineering design process can be applied to nontechnical as well as technical problem areas. During the design process, a plan or model is conceived and developed. This is when research, theory, experience, and practice are used to identify ideas and develop alternative solutions to particular problems; this is also the process that seems to be missing from most of the linking agent models described in Table 1.

Engineering is problem solving and includes the application of research, but it also deals with experience and practical operational concerns. The

engineer is a type of linking agent who bridges the gap between technological advances and the industry or individual seeking problem solutions.

Educational Engineering

There is an apparent equipollence between education and engineering. The educational change agent is analogous to the engineer concerning problem solving. As an example, the problems an industrial engineer solves are both social and technical and seem to be related to the kinds of problems found in education. It seems reasonable, then to apply the basic definitions, concepts, and processes of engineering to education.

Table 2 compares the engineering processes required for bridge construction to those required for curriculum construction to illustrate the transferability of these processes. It can be noted from the table that information retrieval is an activity which seems to be limited to the planning and design phases. Also, the importance of client collaboration is illustrated by the integration of this activity through all of the processes.

Educational engineering may thus be defined as the process in which a knowledge gained from research, experience, and practice, is applied, with judgment, to develop ways to economically use the materials and activities of the school for the benefit of student learning. An important role of the educational engineer should be the specific application of theory, research, and experience to solve problems in the schools, but just as the definition of engineering imposes an economic restraint upon the development of engineering outcomes, so, too, educational engineering must develop its products and processes within the economic limitations

TABLE 2
The Transferability of Engineering Processes to Education

Engineering Process	Bridge Construction	Curriculum Construction
Planning	Collaboration with client. Information retrieval. Specification of current and desired situations.	Staff and community involvement. Information retrieval. Specification of needs and objectives.
Design	Collaboration with client. Review of information. Identification of restrictions and variables related to laws, location, materials, forces, loads, costs. Creative application of ideas. Preparation of blueprints.	Staff and community involvement. Review of information. Identification of restrictions and variables related to regulations, staffing, materials, scheduling, costs. Creative application of ideas. Preparation of curriculum guides.
Analysis	Collaboration with client. Compare drawings with planning and design parameters.	Staff and community involvement. Compare guides with planning and design parameters.
Construction	Collaboration with client. Build towers, anchorages, cables, decks.	Staff and community involvement. Purchase materials, train staff.
Appraisal	Collaboration with client. Evaluate safeness, acceptance, utility.	Staff and community involvement. Evaluate implementation, progress, outcomes.

of the schools. The educational engineer is a linking agent; however, the concept of educational engineering embraces more than just linking resources to practioners. The prime concerns of the educational engineer also include economic feasibility, safeness, public acceptance, and producibility.

The engineering analogy has also helped identify certain assumptions for educational engineering. These assumptions include:

I. Actual and potential learning problems can be reduced by a preventive approach to problem solving defined by educational engineering applications.

II. No school component can be completely autonomous in making decisions about the total educational system.

III. A necessary prerequisite for the implementation of engineering recommendations is a staff commitment to use and evaluate them.

The Implementation of Educational Engineering

The Central Susquehanna Intermediate Unit, as a regional education service agency, has attempted to establish the concept of educational engineering through an ESEA Title IV-C project funded through the Pennsylvania Department of Education (Lutz, 1977). The goal of the project is to improve the effectiveness of schools through better use of theory, research information, and experience in the design of alternative solutions to educational problems. The educational engineer can provide information, but emphasis has been placed upon collaboration, creative design, implementation, and follow-up evaluation. A specific job description has been prepared for the educational engineer to stress these activities; generally, the educational engineer must have had teaching and

some administrative experience, should represent a process generalist, and is required to work in the field with teachers and administrators on matters related to education and engineering.

Personal visits have been made to public and non-public school administrators and teachers to discuss and clarify previously expressed needs, to clarify the role of the educational engineer, and to obtain district commitment and support for participation. A collaborative partnership between the administrator, teacher, and educational engineer has been established and has resulted in an identification of district resources, an assessment of local needs and problems and an analysis of specific student needs, and an accounting of the special conditions and influences which could support engineering changes.

The educational engineering project has had three primary objectives during its initial stages. The first was to develop a working definition for the role of educational engineering for school and instructional improvement. This paper represents the progress made toward reaching this objective.

The second initial objective was to contact each constituent school district within the CSIU. All 17 school districts have been visited; all superintendents have given a positive reaction to the engineering concept and have allowed the educational engineer to make further contacts within the system. Requests were received for work in 12 problem areas which have been classified into three types--curriculum, communications, and retrieval and dissemination of information. Curriculum concerns include a program for special learning problems, integration of instruction for gifted students, integration of elementary art and music activities, improvement of a basal reading program, and the refinement of a course on law in government. Communications concerns included reaching non-committed

students, supporting the identity of non-teaming teachers in a school which emphasizes the team approach, and sharing effective strategies designed by elementary school teachers. Requests for the retrieval and dissemination of information included those for comparisons of basal reading textbooks and of standardized testing programs.

The research literature indicated that during this initial phase of linking, no problems should be turned down. The literature also indicated that linking agent teams could be more effective than single linkers. The major advantages of an engineering team approach include the ability to manage comprehensive and complex problems (those that could take one person several months or even years to solve) and to involve several specialities that no one person could possess, but that a team could effectively represent (Krick, 1978). Graduate and undergraduate students from nearby colleges and universities have been recruited to serve on these teams as engineering interns. The interns' responsibilities include information retrieval and interpretation, on-site visitation and collaboration as an assistant to the educational engineer, and the preparation of first drafts of engineering reports.

A third initial objective of the project has been to develop a training manual for educational engineering. Thus far, appropriate linking agent research information has been identified and screened for the manual. Staff development activities are also being identified and evaluated for the same purpose.

Engineering reports for classroom teachers have been planned to address each problem area identified by participating teachers. These engineering reports have been designed to follow a planning format and will include a brief description of the current state of affairs and the identification of the problem, a brief

description of the desired state of affairs, a listing of the identified restrictions and criteria for alternative solutions, the variables desired for the design of solutions, the recommendations and procedures for solving the identified problem, and an evaluation strategy for appraising the effectiveness of the recommended solution. In addition to preparing engineering reports, the engineering team and the educational engineer will help participating teachers implement and evaluate the planned activities. Similarily, engineering reports have been planned for school administrators to address the problems identified for the support of classroom instruction and student achievement and in non-instructional support areas.

Basic to educational engineering is the use of research information, and one of the most important criteria for the use of this information is its replicability and generalizability (Pursell, 1978). The most useful research information is that which includes a related theoretical framework, a description of specific procedures and participants, experimental validity, and useful results. Also useful is more informal or quasi-experimental research which describes assumptions underlying the particular study, the activities used, and the results found. Usable information is the accepted authority judgment which includes articles written by persons recognized by training, experience, or writings as educational experts and which includes source and activity descriptions to establish some basis in fact. Finally, other usable information includes the accepted authority opinion which is based upon or implied from experience or general activity descriptions.

The engineering processes require an open attitude toward the potentials for problem solutions. Research information can describe and suggest replicable

activities, but other ideas generated from available information should not be discounted, even if they seem remote or too simple to be useful. A creative approach to problem-solving must be encouraged which allows new ideas and new arrangements to be proposed for possible solutions to given problems. Activities can be adopted directly from available research, if a particular problem is the same as that described in the research. In other situations, ideas stimulated by the research can serve as the catalyst for innovative and economical alternatives.

The subsequent activity to the design and implementation of proposed solutions to educational problems is evaluation. It is most important to determine whether or not the identified problems have been solved as a result of the engineering activities. Evaluation will, in turn, contribute to the research information base directly with valid and reliable information produced from evaluation studies, and indirectly with calls for further work by others to fill recognized gaps in the research base.

Conclusions

The thesis of this paper is that the rate of change and improvement in the public schools has been checked by the absence of an engineering component (and the educational engineer as a change agent). Education as a science is maturing; that is, knowledge obtained through educational research and evaluation is becoming more reliable, valid, and usable for the definition of educational theory and the predictive power provided by theory. The processes to apply the results of educational research to utilize new reliable and valid information and to profit from the experiences and creativity of educators to supply human needs in learning must be more formally established. Educational engineering, as a discipline, is

needed to fill the gaps identified in the current literature on educational linking agents which relate to the utilization and implementation of research information, the development of proto-theory and theory, and the general improvement of the effectiveness and cost-efficiencies of education.

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